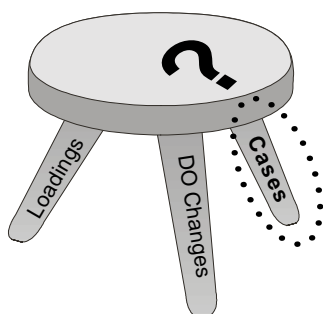# Chapter 4

Case Study Assessments of Water Quality

In the previous chapter, the national-scale evaluation of long-term trends in water quality conditions identified numerous waterways that were characterized by substantial improvements in worst-case DO after the CWA (from 1961-1965 to 1986-1990). The signals of worst-case DO improvements that have been detected from the "noise" of the STORET database document the tremendous progress that has been achieved as a result of implementation of the CWA in 1972. Having identified numerous watersheds and RF1 reaches, however, the inquisitive reader could easily list a number of questions to fill in the information needed to tell a more complete history about environmental management and water pollution control decisions in these watersheds.

Typical questions might include the following: What are the population trends? Are point or nonpoint sources the largest component of pollutant loading? What have been the long-term trends in effluent loading from municipal and industrial sources over the past 25-50 years? Has industrial wastewater loading declined because obsolete manufacturing facilities have been abandoned? What have been the long-term trends in key water quality parameters over the past 25-50 years? Have reductions in wastewater loads had any impact on biological resources or recreational activities?

This third leg of the three-legged stool approach focuses on answering these types of questions. The uniqueness of each watershed requires an investigator to go beyond STORET and other centralized databases to identify, obtain, and compile sufficient historical data to answer these questions and others. By necessity, the selection of specific waterways based on case studies has often been used as an appropriate technique for policy evaluations of the environmental effectiveness of water pollution control decisions. That technique is used in Chapters 5 through 13 of this document.

A. Background

Less than a decade after enactment of the 1972 CWA, Congress and the public began to raise policy questions about the national-scale effectiveness of the technology-based controls of the CWA. In attempting to provide some answers to these questions, case studies of water pollution control and water quality management were compiled for a number of streams, rivers, lakes, and estuarine waterbodies. To meet a variety of objectives, both anecdotal and quantitative data and information have been collected for case studies evaluating water quality conditions.

Anecdotal accounts of historical water pollution problems and changes in the water quality of streams, rivers, estuaries, and coastal waters that had been achieved by the early 1980s were reported by state agencies and compiled by USEPA (1980) and the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA, 1984). Twenty-five years after enactment of the 1972 CWA, USEPA (1997) and the Water Environment Federation (WEF, 1997) reported on the substantial water quality improvements that had been achieved in rivers, lakes, estuaries, and coastal waters. Based on anecdotal evidence, these reports concluded that the CWA had produced substantial gains in water quality. No quantitative data were presented, however, in either of these reports to support the conclusion that the goals of the CWA were being achieved.

In a 1988 quantitative synthesis of before-and-after studies, USEPA (1988) compiled the results of 27 case studies to document water quality changes that had resulted from upgrades to municipal wastewater treatment facilities (primary to secondary, or secondary to advanced treatment). With the exception of only a few cases (e.g., Potomac estuary near Washington, DC, and Hudson River near Albany, New York), most of the 27 cases accounted for both minor and major facilities (< 0.1 to 30 mgd) discharging to small receiving waters with 7Q10 low flows ranging from < 1 cfs to 100 cfs. Based on pollutant loading and water quality data sets, 23 of the 27 case studies were characterized by at least moderate improvements in water quality conditions after upgrades of the POTWs. Included in USEPA's 1988 synthesis were the well-documented before-and-after findings of Leo et al. (1984), based on 13 case studies of water quality changes that were linked to upgrades from secondary to advanced treatment. Also included in USEPA's synthesis were four case studies prepared by GAO (1986a) of municipal upgrades for rivers in Pennsylvania: Lehigh River, Allentown (30 mgd); Neshaminy Creek, Lansdale (2.36 mgd); Little Schuykill River, Tamaqua (1.09 mgd); and Schuykill River, Hamburg (0.46 mgd).

A number of case studies other than those presented in this report have documented trends in improvements in water quality conditions and biological resources following site-specific upgrades. Estuarine case studies of pollutant loading, water quality trends, fisheries, and other biological resources have been prepared for Narragansett Bay (Desbonnet and Lee, 1991), Galveston Bay (Stanley, 1992a), the Houston Ship Channel (EESI, 1995), and Pamlico-Albemarle Sound (Stanley, 1992b).

For Lake Washington in Seattle, Edmondson (1991) documented the long-term ecological impact of the diversion during the mid-1960s of municipal wastewater on cultural eutrophication and recovery of a large urban lake. The rejuve-

nation of Lake Erie, declared "dead" during the 1960s, is positive evidence that the regulatory controls of the 1972 Clean Water Act and the 1972 Great Lakes Water Quality Agreement between Canada and the United States, designed to mitigate bottom water hypoxia and cultural eutrophication by reducing pollutant loads of organic matter and phosphorus, have been successful in greatly improving water quality (Burns, 1985; Charlton et al., 1995; Sweeney, 1995) and ecological conditions (Krieger et al., 1996; Koonce et al., 1996; Makarewicz and Bertram, 1991) in this once ecologically devastated lake. The Cuyahoga River, a major tributary to Lake Erie at Cleveland, Ohio, sparked national attention when the river caught fire in 1969, helping to push the U.S. Congress to pass the Clean Water Act in 1972 (NGS, 1994). Three decades after the infamous fire, although some water quality problems remain to be solved (e.g., urban runoff and CSOs), water quality is greatly improved. Tourist-related businesses and recreational uses along the riverfront are thriving, as are populations of herons, salmon, walleye, and smallmouth bass (Hun, 1999; Brown and Olive, 1995).

In freshwater river systems, Isaac (1991) presented long-term trends (1969-1980) of DO in the Blackstone, Connecticut, Hoosic, and Quinebaug rivers in Massachusetts to document water quality improvements after upgrades of municipal facilities to secondary treatment. Using a wealth of historical data compiled for New England, Jobin (1998) presents a number of case studies documenting long-term trends in pollutant loading and water quality for freshwater rivers (e.g., Neponset, Charles, Taunton, Blackstone) and estuarine systems (e.g., Boston Harbor, Narragansett Bay). In the Midwest, Zogorski et al. (1990) prepared a case study of the Upper Illinois River basin to evaluate the availability and suitability of water quality and effluent loading data as a demonstration of the methodology for use in national assessments of water quality trends. Zogerski et al. concluded that although a large amount of the required data is available from national and state databases, *the suitability of the existing data to accomplish the objectives of a national water-quality assessment is limited.*"

In another midwestern river, a statistical before-and-after analysis of water quality in the White River near Indianapolis, Indiana, clearly showed improvements in DO, ammonia, and BOD_5 after an upgrade from secondary to advanced treatment (Crawford and Wangness, 1991). (See discussion in Chapter 3.) Similar water quality improvements have also been documented for the Flint River in Georgia and the Neches River in Texas (Patrick et al., 1992). Becker and Neitzel (1992) have compiled case studies of the impacts from water pollution and other human activities on water quality, fisheries, and biological resources for a number of major North American rivers. Another success story in the Pacific Northwest has documented both water quality and economic benefits achieved by water pollution control in the Boise River in Idaho (Hayden et al., 1994; Noah, 1994).

B. Selection of Case Study Waterways

Following the precedent established by these earlier before-and-after assessments of changes in water quality that can be attributed, in part, to the CWA, a number of freshwater and estuarine waterbodies were selected as case studies for this report. Criteria for the selection of case study sites included the following:

- The major river or estuarine system was identified in the 1960s as having gross water pollution problems.

- The major river or estuarine system lies in a major urban-industrial region.

- Municipal wastewater is a significant component of the point source pollutant load to the system.

- Water quality models were available to evaluate the water quality impact of simulated primary, secondary, and actual effluent scenarios for municipal dischargers.

- Historical data were readily available.

Table 4-1 provides the 1996 population for the Metropolitan Statistical Areas (MSAs) and counties included in the case study, and the types of data and information compiled for each river or estuarine waterbody selected as a case study. The population of the case study MSAs (43.2 million) accounted for 16 percent of the Nation's total population in 1996 (265.2 million) (USDOC, 1998). Figure 4-1 shows the location of the case study watersheds. In contrast to some of the other case study assessments discussed previously, the case studies in this report were specifically selected because they represent large cities located on

Table 4-1. Case study assessments of trends in water quality and environmental resources. *(Source: USDOC, 1998)*

| Case Study	1996 Study Area Population (millions)	Information Presented					
		Population	Pollutant Loads	Water Quality	Environmental Resources	Recreational Uses	Water Quality Model
Connecticut River	1.109	✓	✓	✓	✓	✓	
Hudson-Raritan Estuary	16.991	✓	✓	✓	✓	✓	
Delaware Estuary	5.973	✓	✓	✓	✓	✓	✓
Potomac Estuary	4.635	✓	✓	✓	✓	✓	✓
James Estuary	2.237	✓	✓	✓	✓	✓	✓
Upper Chattahoochee River	3.528	✓	✓	✓	✓	✓	
Ohio River	3.779	✓	✓	✓	✓	✓	
Upper Mississippi River	2.760	✓	✓	✓	✓	✓	✓
Willamette River	2.149	✓	✓	✓	✓	✓	
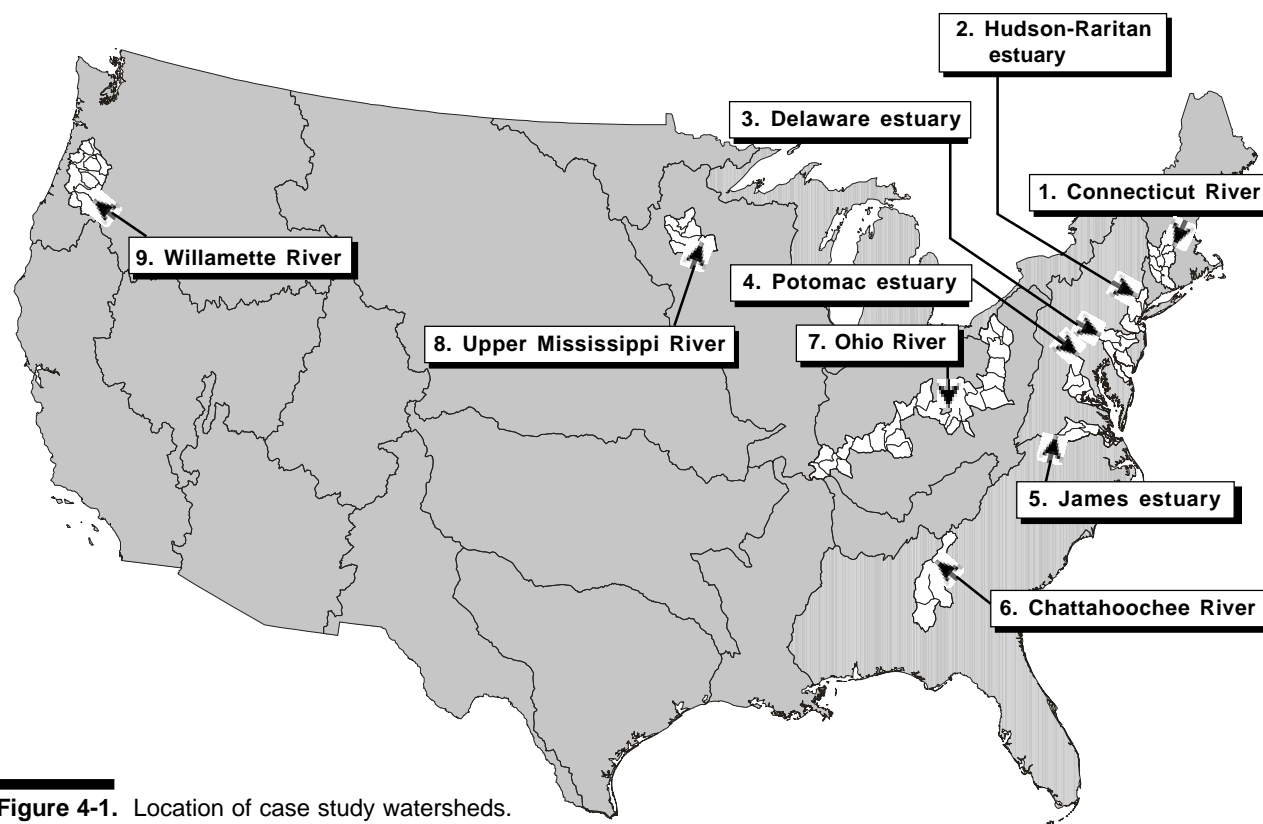
Figure 4-1. Location of case study watersheds.

major waterways known to have been plagued by serious water pollution problems during the 1950s and 1960s (Table 4-2). Many of the case study waterways either were the sites of interstate enforcement conferences from 1957 to 1972 or were listed by the federal government as being potential waterways to convene state-federal enforcement conferences in 1963 (Zwick and Benstock, 1971). Two of the case studies, the Ohio River and tributaries to New York Harbor (Passaic River and Arthur Kill), were identified by the federal government in 1970 in a list of the top 10 most polluted rivers (Zwick and Benstock, 1971). The Department of the Interior identified all the estuarine case study sites as waterways suffering from either low oxygen levels or bacterial contamination in a national study of estuarine water quality (USDOI, 1970). All but two of the case study areas were the subject of water quality evaluation reports prepared for the National Commission on Water Quality (NCWQ) to provide baseline data to track the effectiveness of the technology-based effluent controls required under the newly enacted 1972 CWA (see Mitchell, 1976).

For all the case studies, data have been compiled to characterize long-term trends (more than 50 years) beginning in 1940 for population, upgrades to municipal wastewater facilities, effluent loading, water quality, environmental resources, and recreational uses. Additional data have been obtained from validated water quality models for the Upper Mississippi River, Potomac estuary, Delaware estuary, and James estuary to quantify improvements in water quality achieved by municipal upgrades from primary to secondary or advanced treatment levels. Data sources include published scientific and technical literature, USEPA's STORET database, and unpublished technical reports ("grey" literature) prepared by consultants and state, local, and federal agencies.

Table 4-2. Identification of gross water pollution problems for case study waterways in government documents. *Sources: Zwick and Benstock, 1971; USDOI, 1970; and Mitchell, 1976.*

Case Study	Potential Enforcement Conference 1963	Enforcement Conference 1957-72	Top 10 Polluted Waterways 1970	NCWQ Case Studies 1976	National Estuarine Pollution Study 1970
Connecticut River	▪	▪		▪	▪
Hudson-Raritan estuary	▪	▪	▪	▪	▪
Delaware estuary				▪	▪
Potomac estuary	▪	▪		▪	▪
James estuary					▪
Chattahoochee River	▪	▪		▪	
Ohio River	▪	▪	▪	▪	
Upper Mississippi River	▪	▪		▪	
Willamette River					

C. Before and After CWA

Using water quality data extracted from USEPA's STORET database (as described in Chapter 3), before-and-after conditions for summer (July-September), 10th percentile DO levels in RF1 reaches selected from the case study watersheds (Figure 4-1) clearly demonstrate dramatic improvements during the period after the CWA from 1986-1995 for all the case study sites (Figure 4-2). Before the CWA, during the 10-year period from 1961 to 1970, "worst-case" DO levels were in the range of 1 to 4 mg/L for most of the case study sites. After the CWA, worst-case DO levels had improved substantially to levels of about 5 to 8 mg/L during 1986-1995, with the worst-case oxygen levels of less than 2 mg/L before the CWA improving to 5 mg/L or higher after the CWA. Great progress has been achieved in improving DO conditions in New York Harbor, the Chattahoochee River, the Delaware River, and the Potomac River.

Water quality improvements in other constituents, including BOD_5, suspended solids, coliform bacteria, heavy metals, nutrients, and algal biomass, have also been linked to reductions in municipal and industrial point source loads for many of the case studies. Figure 4-3 correlates long-term trends in the reduction of effluent loads of BOD_5 with improvements in summer DO in the Upper Potomac estuary (Washington, DC), the Upper Mississippi River (Minneapolis-St. Paul, MN), and the Willamette River (Portland, OR). Finally, improvements in water quality have also been linked to the post-CWA restoration of important biological resources (e.g., fisheries and submersed aquatic vegetation in the Potomac estuary) and increased recreational demand and aesthetic values of waterways once considered extremely unsightly (e.g., Upper Mississippi River).

Figure 4-2

Location map of case study waterways and distribution chart of their before- and after-CWA mean 10th percentile DO for case study RF1 reaches: 1961-1970 vs. 1986-1995. *Source: USEPA STORET.*
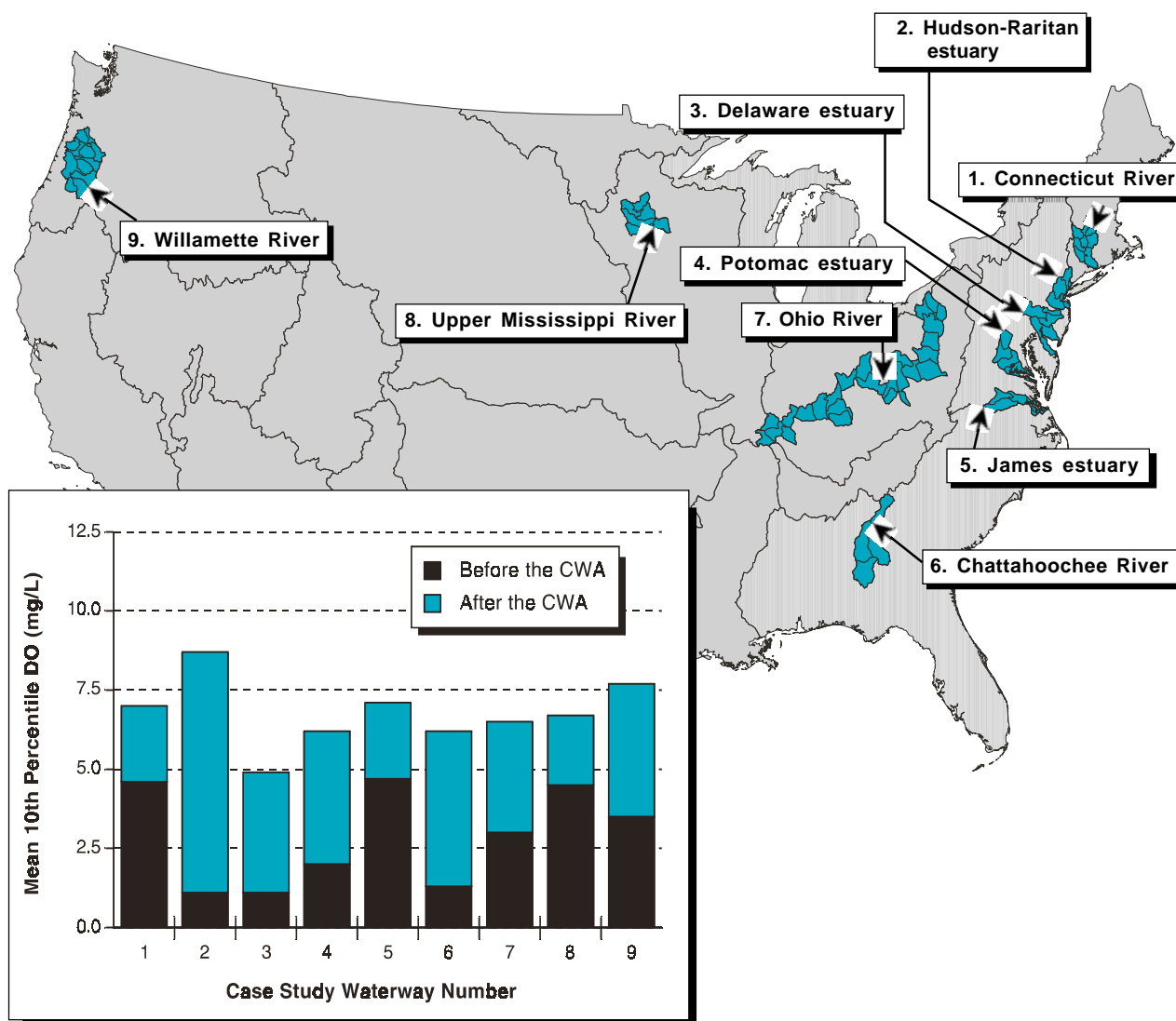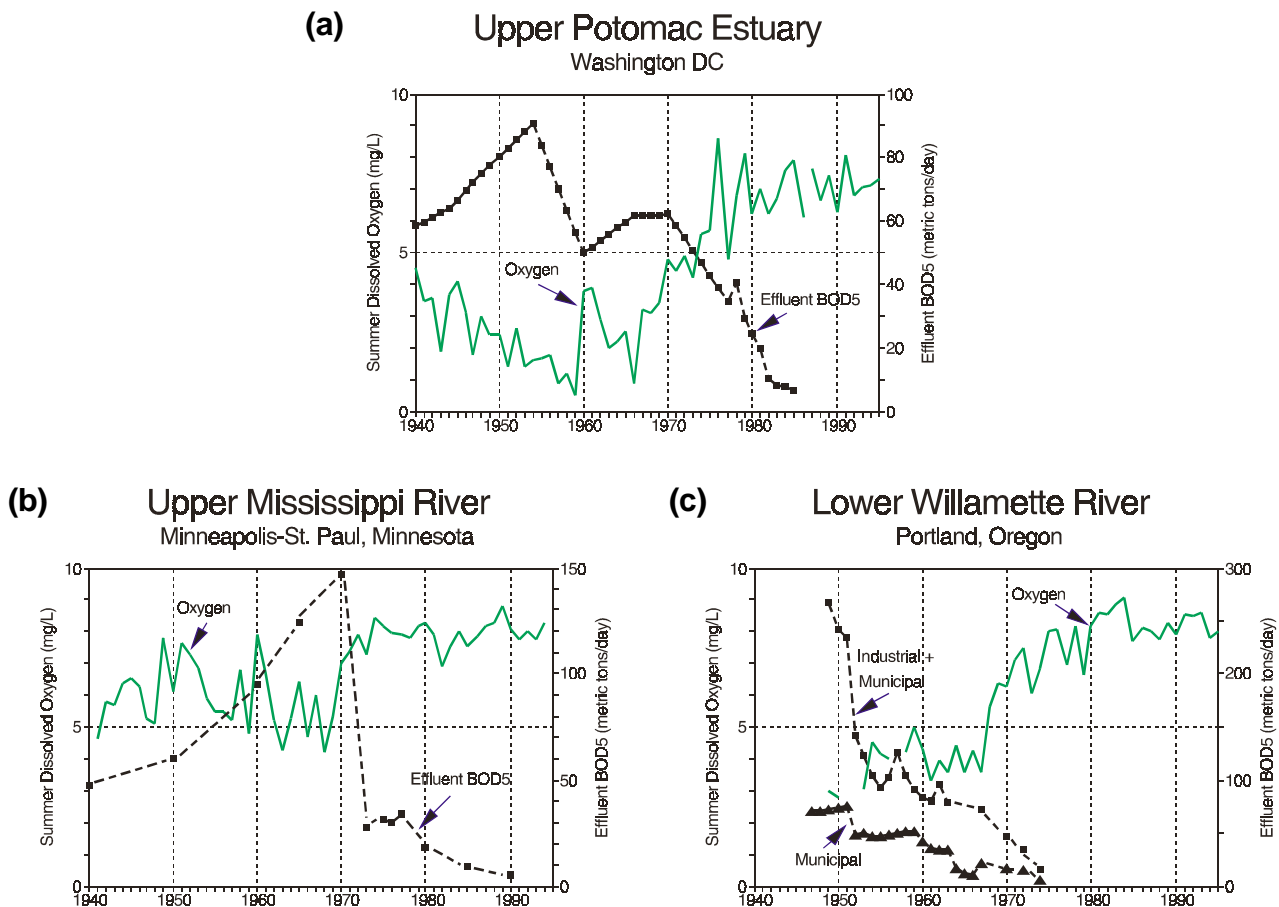
Figure 4-3. Long-term trends of improvements in ambient DO and declines in effluent BOD$_5$ loading for (a) Upper Potomac estuary, (b) Upper Mississippi River, and (c) Willamette River. *Sources: Larson, 1999; Gleeson, 1972; Jaworksi, 1990; MWCOG, 1989; ODEQ, 1970; USEPA STORET.*

D. Policy Scenarios for Municipal Effluent Discharges

Before the 1972 CWA, state officials made waterbody-dependent decisions about the required level of municipal wastewater treatment needed to attain compliance with ambient water quality criteria or standards. After the 1972 CWA, the USEPA implemented a technology-based policy to regulate pollutant loading from municipal and industrial point sources. Under the 1972 CWA, municipalities were required to achieve at least a minimum level of secondary treatment to remove approximately 85 percent of the oxygen-demanding material from wastewater. In cases where the minimum level of secondary treatment was not sufficient to meet water quality criteria or standards, ambient criteria were used to determine a water quality-based level of wastewater treatment greater than secondary treatment. From a policy and planning perspective, the key question for water quality management decision makers is: What level of municipal wastewater treatment is needed to ensure compliance with water quality criteria or standards under critical conditions?

For the Delaware, Potomac, James, and Upper Mississippi case studies, validated water quality models have been used to provide quantitative answers to evaluate the changes in water quality conditions achieved as a result of either actual or hypothetical upgrades to municipal wastewater treatment facilities. Effluent loading rates for the primary and secondary loading scenarios were based on existing population served and effluent flow data with typical effluent concentrations characteristic of primary and secondary treatment facilities; existing loading rates were used to define the better-than-secondary (actual) scenario. Receiving water streamflow was based on the existing "dry" summer streamflow measurements used to validate the models. The water quality models were used to simulate the impact of the primary, secondary, and actual better than secondary loading scenarios on the spatial distributions of DO, BOD_5, nitrogen, phosphorus, and algal biomass.

Figure 4-4 shows the key results for the model simulations for dissolved oxygen simulated at the worst-case critical oxygen sag location along the length
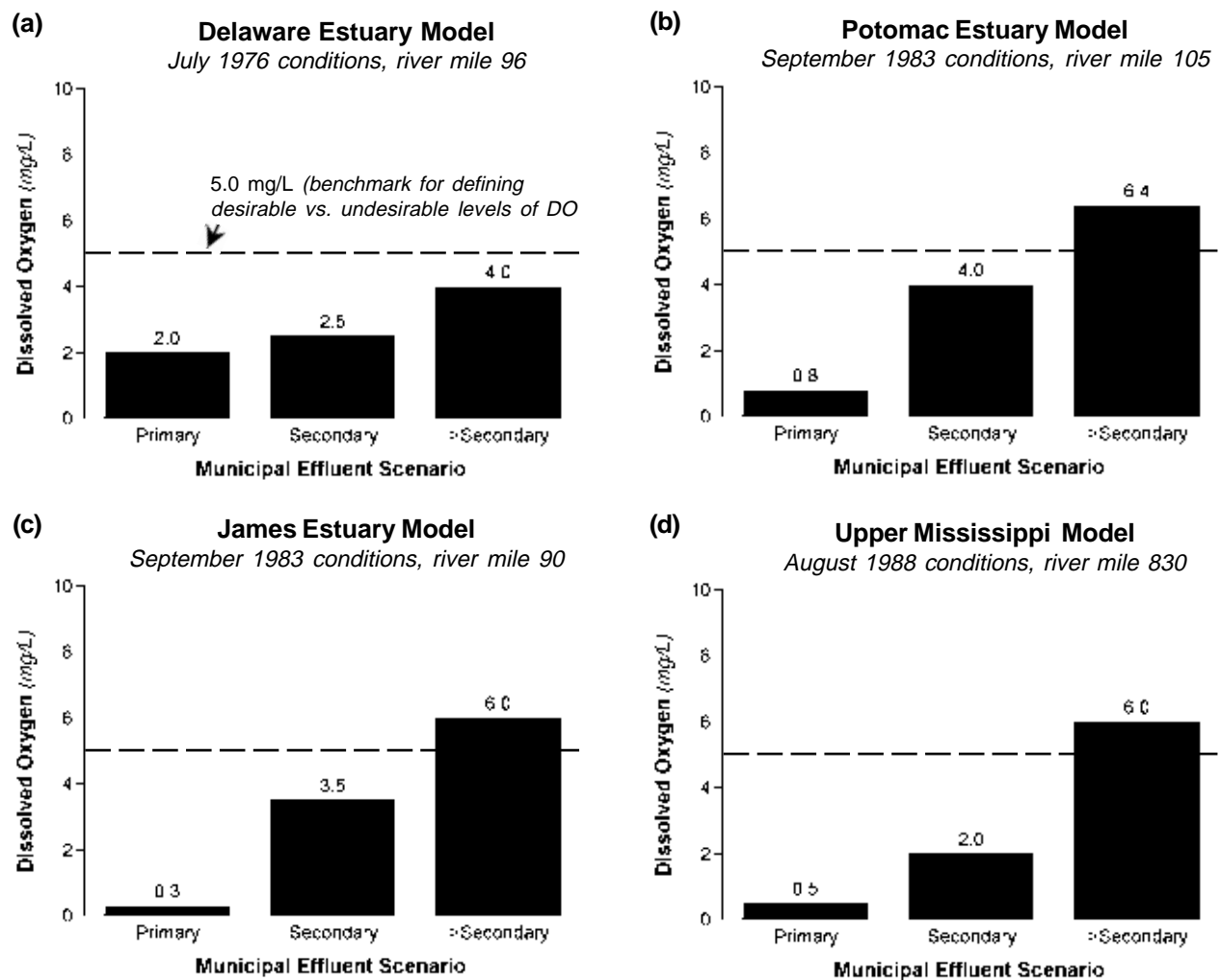

Figure 4-4. Model simulation of DO under summer "dry" streamflow conditions at the critical oxygen sag location for primary, secondary and better-than-secondary effluent scenarios for case studies of (a) Delaware estuary, (b) Potomac estuary, (c) James estuary, and (d) Upper Mississippi River. *Sources: Clark et al., 1978; Fitzpatrick et al., 1991; HydroQual, 1986; Lung, 1998; Lung and Larson, 1995; Lung and Testerman, 1989.*

of each river. As shown in these results, the primary effluent scenario results in extremely poor conditions with DO levels of less than 1 mg/L for the Potomac, James, and Upper Mississippi cases and 2 mg/L for the Delaware. The model results for the primary scenario of severe oxygen depletion are, in fact, consistent with historical oxygen data recorded for these rivers during the 1960s. Simulating an upgrade to secondary treatment, as mandated by the 1972 CWA for municipal facilities, DO conditions are improved but are still less than the benchmark concentration of 5 mg/L often used to describe compliance with water quality standards. As demonstrated with the models, and actually achieved, better-than-secondary levels of municipal treatment are needed to exceed a benchmark of 5 mg/L for DO. In contrast to the poor water quality conditions common in these rivers during the 1960s, the occurrence of low DO levels has been effectively eliminated, even under severe drought conditions, as a result of upgrades beyond primary treatment to better-than-secondary levels of waste treatment.

E. Discussion and Conclusions

In developing a methodology to evaluate the effectiveness of USEPA's Construction Grants Program, GAO (1986b) posed four questions to evaluate the water quality benefits obtained from upgrading municipal wastewater treatment facilities:

1. Did upgrading the POTW decrease the amount of pollutants discharged?

2. Did water quality improve downstream from the POTW?

3. Is there a relationship between changes in a plant's effluent and changes in stream water-quality indicators?

4. Can other reasonable explanations of a stream's water quality be excluded?

Although many of the case studies in this report (Chapters 5 through 13) include a mix of multiple municipal and industrial wastewater discharges and might not be applicable to the methodology developed by GAO (1986b), the dramatic improvements that have been documented for effluent loading, water quality, environmental resources, and recreational uses clearly suggest that the answer to the questions raised by GAO (1986b) for all nine case studies is an overwhelming "yes."

In addition to the case study questions posed by GAO, the national policy questions raised by Congress and the public can be modified slightly to use for evaluations of the case study waterways: *Has water quality improved as a result of public and private capital improvement expenditures for water pollution control? Has the waterbody achieved the "fishable and swimmable" goals set forth in the CWA? Has the CWA worked?*

For all the case study waterways, tremendous progress has been made in improving water quality, restoring valuable biological resources, and creating thriving water-based recreational uses of the waterways that contribute to the local economies. Although significant progress has been achieved in eliminating noxious water pollution conditions, nutrient enrichment, and sediment contamina-

Conclusion of the third leg of the stool
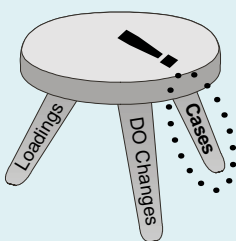
Tremendous progress has been achieved in improving water quality, restoring valuable biological resources, and creating recreational opportunities in all the case study areas!

tion, heavy metals and toxic organic chemicals continue to pose threats to human health and aquatic organisms. Serious ecological problems remain to be solved for many of the Nation's waterways, including the case study sites. The evidence is overwhelming, however, that the national water pollution control policy decisions of the 1972 CWA have achieved significant successes in many waterways. With the new watershed-based strategies for managing pollutant loading from point and nonpoint sources detailed in USEPA's *Clean Water Action Plan* (USEPA, 1998), the Nation's state-local-private partnerships will continue to work to attain the original "fishable and swimmable" goals of the 1972 CWA for all surface waters of the United States.

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